Using GLOBE and Other Observations to Validate Meteorological Models

Christopher A. Hiemstra and Roger A. Pielke, Sr.
Department of Atmospheric Science
Colorado State University
Fort Collins, CO 80523-1371, USA
PH: (970) 491-3647 FAX: (970) 491-3314
e-mail: hiemstra@atmos.colostate.edu

Introduction

Meteorological forcing data are necessary to drive many of the spatial models used to simulate atmospheric, biological, and hydrological processes (e.g., Liston and Sturm 1998, Hiemstra 2003, Liston 2003). Unfortunately, many areas (e.g., high elevations, mountain slopes, deserts) lack meteorological data and available point observations are not always suitable for landscape or regional applications, especially in mountainous regions.
The local analysis prediction system (LAPS, http://laps.fsl.noaa.gov/) is a meteorological diagnostic tool that employs observations (meteorological networks, radar, satellite, soundings, and aircraft) to generate a spatially distributed, three-dimensional representation of atmospheric features and processes (Albers et al. 1996). Data produced by LAPS include wind speed, wind direction, surface temperature, relative humidity, surface pressure, precipitation, and cloud cover. Because LAPS is a spatially distributed representation of meteorological observations, it provides valuable opportunities for users requiring local (10 km horizontal grid increment) meteorological data to drive distributed land surface and ecosystem models over large regions (1.29×10^6 km^2).
As with any diagnostic representation, it is important to ascertain how LAPS outputs deviate from a variety of observations at different spatial and temporal scales. Since many observations are integrated into LAPS, they cannot be used to assess assimilative performance. Fortunately, a number of observations exist that are not used in LAPS. Our objective is to assess how well LAPS diagnoses represent atmospheric characteristics (e.g., air temperature, relative humidity, wind speed) and incoming precipitation within the LAPS domain during a 2-year period (1 September 2001 – 31 August 2003).

Methods

Validation of LAPS diagnoses required hourly LAPS assimilations, independent meteorological observations, supporting geographic data, and statistical analyses. LAPS validations were performed for diagnoses spanning 1 September 2001 – 1 September 2003 over the 53,129 km^2 domain of interest (Fig. 1).

Validation required the comparison of LAPS diagnoses with meteorological data that were not used in the analyses. One hundred and six independent stations were operated by educational and agricultural observational networks and a field experiment campaign (Fig. 1).

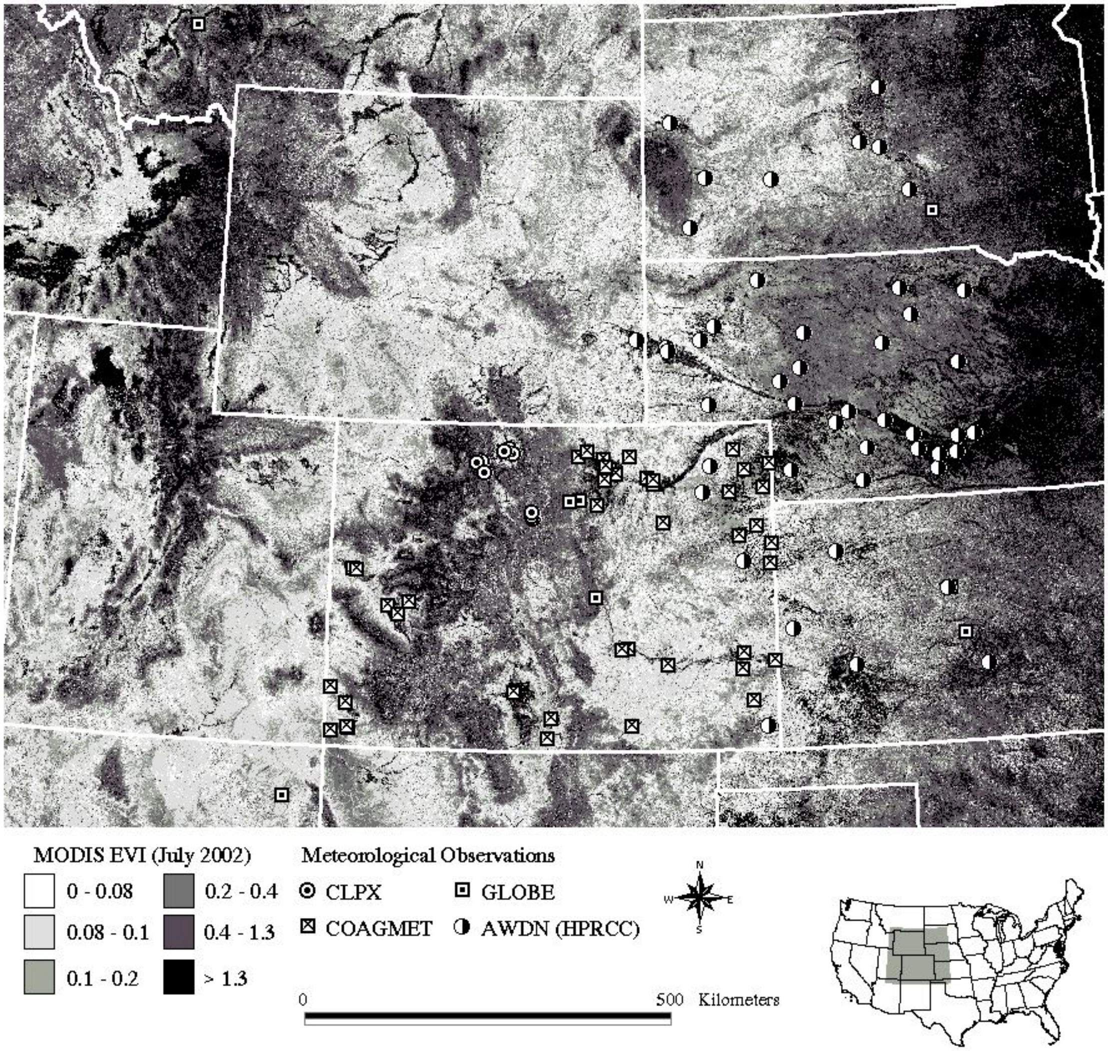

Figure 1. The LAPS domain, portrayed in this MODIS enhanced vegetation index (EVI) image, envelops Colorado, Wyoming, and portions of surrounding states. Data used for validation include the Cold Land Processes Experiment (CLPX), Colorado Agricultural Meteorological Network (COAGMET), GLOBE, and the High Plains Regional Climate Center's Automatic Weather Data Network (AWDN).

Data sources utilized for validation included the Cold Lands Processes Experiment (CLPX), the Colorado Agricultural Meteorological network (COAGMET, http://ccc.atmos.colostate.edu/~coagmet/), the GLOBE program (http://www.globe.gov/), and the High Plains Regional Climate Center's Automatic Weather Data Network (AWDN, http://www.hprcc.unl.edu/awdn/). Collected data were processed, quality checked, and spatially matched with corresponding LAPS output for validation.

The LAPS validation process occurred in two principal steps. In the first step, LAPS data were compared directly with observations using simple linear regressions. The direct comparisons included air temperature, relative humidity, wind speed, and precipitation. The second step entailed the assessment of errors identified in the first step with respect to the location and elevation of the observations.

Results and Discussion

Simple Linear Regressions

Temperature and relative humidity diagnoses and observations exhibit high levels of agreement, or r^2 values (Figs. 2 and 3). Wind speed possesses the highest variation of the compared characters, ranging from an r^2 of 0.01 to 0.85. Lastly, the comparison between precipitation values produced by LAPS and the observations indicated a poorer (r^2 = 0.20-0.40) agreement.

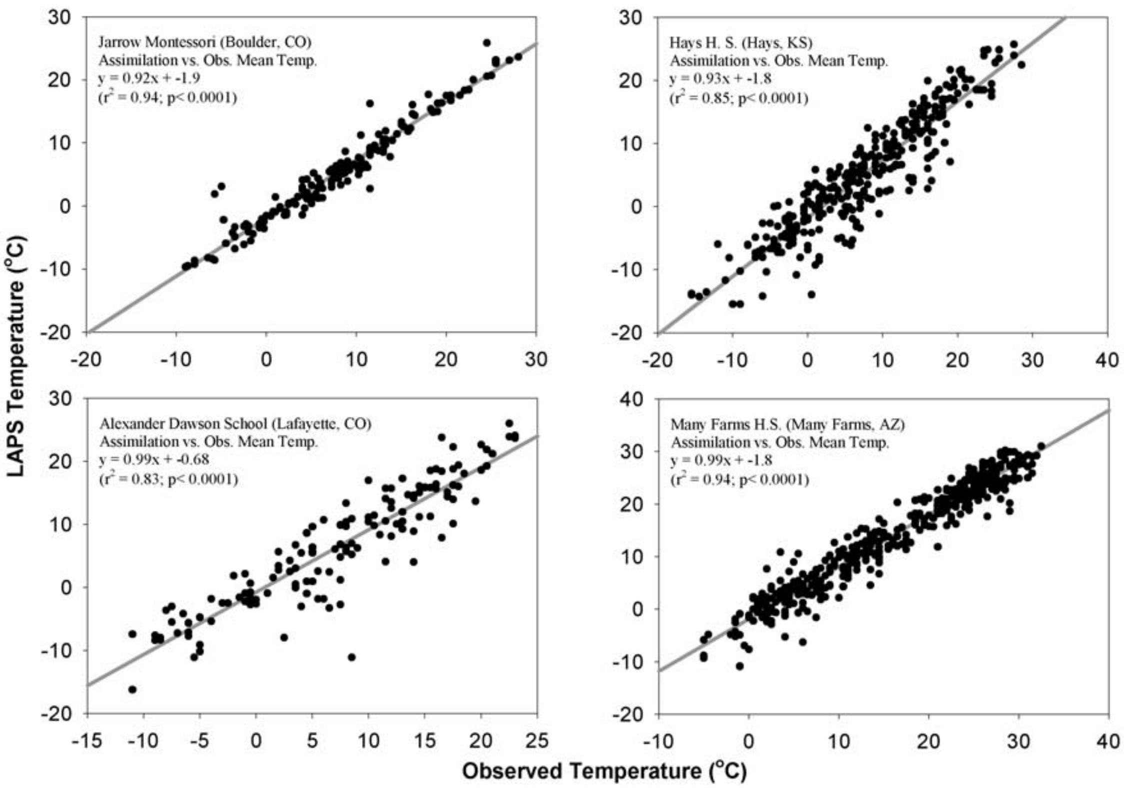

Figure 2. Simple linear regressions were performed for concurrent observed and LAPS assimilated daily mean air temperatures (°C) for four selected GLOBE sites. The data were collected between 1 Sep. 2001 and 31 Aug. 2003.

Agreement and Land Cover

ANOVA analyses (not shown) performed to assess mean r^2 values indicated that temperature, relative humidity, and wind speed agreements changed significantly with land cover types. However, the variation was often minor in magnitude and only one land cover type deviated significantly from the other types (air temperature, residential; relative humidity, alpine; wind speed, evergreen forest). Further, the number of stations located in grassland or cropland environments greatly outnumbered the other land cover classes, leading to an unbalanced assessment of land cover effects on observed and assimilated agreements.

Discrepancies in Wind Speed and Precipitation

The high agreement associated with observations and LAPS diagnoses of temperature and relative humidity are impressive, but the agreements between wind speed and precipitation have a larger range and are lower (Fig. 3). The direction and magnitude of temperature and relative humidity changes, generally, are more spatially continuous and change more slowly compared with wind speed and precipitation. For instance, the level of agreement between observed and assimilated wind speed decreases with increasing elevation (Fig. 4). This decomposition in agreement with increasing elevation is likely tied to irregular terrain, local vegetative features (e.g., trees which are absent at lower elevations), the LAPS calculation procedure , or perhaps increased distance from observations used by LAPS to create assimilations.

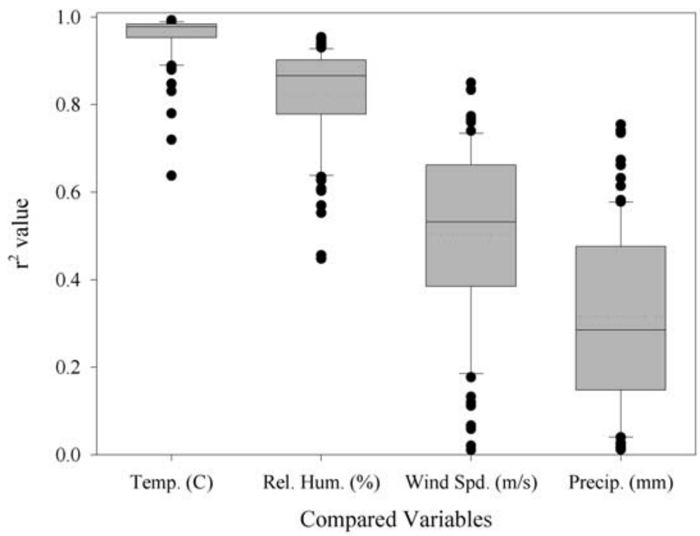

Figure 3. The variability in the LAPS assimilations accounted for in the observations is represented by the r^2 value produced by simple linear regressions. The box plots display the mean (dashed line); median (solid line); and 10th, 25th, 75th and 90th percentiles of the r^2 values. Temperature and relative humidity values possess the highest agreement among LAPS diagnoses and observations. Wind speed and precipitation agreement is lower and more variable.

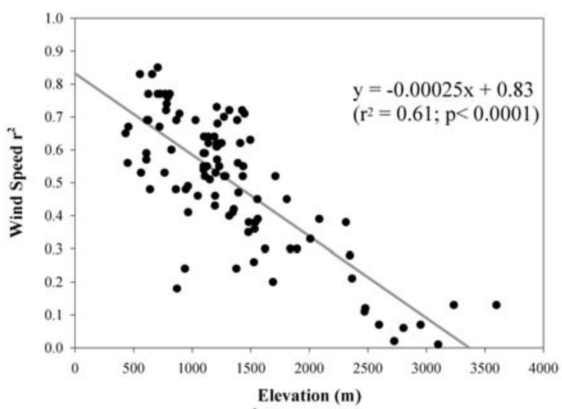

Figure 4. Wind speed comparison r^2 values decrease with elevation. The decrease with elevation may be related to local terrain influence, LAPS topography resolution, and LAPS wind profile calculations.

The relationships between observed and LAPS assimilations of precipitation were universally poor, regardless of the geographical situation. Reasons for the lack of agreement between observed and LAPS precipitation estimates remain unaddressed but likely involve different sampling footprints in satellite and radar estimates versus point observations.

Summary

Validation of any diagnostic tool (e.g., LAPS) is a critical step in understanding how well weather and climate processes are represented. Further, it is important to quantify error introduced by using LAPS data to drive distributed land surface models. Extensive validation of LAPS assimilations with independent data over the period from 1 Sep. 2001 to 31 Aug. 2003 indicates that real-world air temperature, relative humidity, and, in most locations, wind speeds are closely diagnosed by LAPS assimilations. The ability of LAPS to produce reasonable atmospheric diagnoses for a variety of land cover types over a large region makes it a valuable tool for atmospheric scientists, climatologists, ecologists, and hydrologists.

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